

simulation and theory to be  $z = 1/3$  (Laradji & Sunil Kumar, 2004). When the area fraction is increased to 50% of the surface of the membrane, simulation predicts  $R \propto t^{1/2}$  (Fan et al., 2010; Laradji & Sunil Kumar, 2005). Here we compare physical measurement of the growth exponent to theory in both cases. We also show preliminary evidence of Ostwald ripening on GUVs.

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#### 2738-Pos Board B724

##### Endophilin N-Bar Domain is Sorted by Membrane Curvature in a Solution Concentration-Dependent Manner

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Membrane curvature provides an active means to control spatial organization and activity of cells and is regulated and explored by a plethora of peripheral membrane proteins, including dynamin, as well as proteins containing BAR domains and amphipathic membrane-binding helices. The protein endophilin has been shown to be involved in curvature-sorting phenomena during clathrin-mediated endocytosis in neuronal synapses. The mechanisms underlying its curvature-sorting are currently unclear. In addition to scaffolding effects contributed by its BAR domain and N-terminal hydrophobic helix membrane insertion, oligomerization likely contributes to membrane curvature sensing and generation.

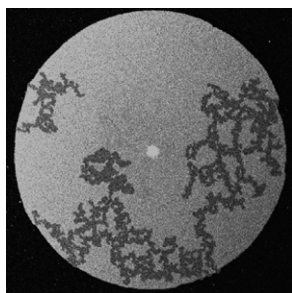
In order to enhance the biophysical understanding of membrane curvature sorting, we are using the following approach. Highly bent cylindrical membrane tethers are pulled from pipette-aspirated giant vesicles. Fluorescence images revealed that rat A1 endophilin N-BAR domains (E-N-BAR) preferentially partitioned onto the tethers rather than the low curvature vesicles. We quantified the sorting of E-N-BAR via image analysis of confocal microscopy tether cross section images. We found that curvature-sorting of E-N-BAR characteristically depends on aqueous solution protein concentrations. Ratiometric assessments of curvature-partitioning at two different solution concentrations furthermore revealed nonlinear trends in curvature composition coupling. We also developed a new thermodynamic curvature/composition coupling model to analytically interpret our measurements. In addition, our findings from fluorescence photobleaching recovery (FPR) measurements showed that diffusion coefficients of E-N-BAR on tethers decrease with increasing membrane curvature, revealing curvature-dependent molecular crowding consistent with our curvature sorting theory.

#### 2739-Pos Board B725

##### Fractal Avalanche Ruptures in Biological Membranes

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Bilayer membranes envelope cells as well as organelles; constitute the most ubiquitous biological material found in all branches of the phylogenetic tree. Cell membrane rupture is an important biological process and substantial rupture rates are found in skeletal and cardiac muscle cells under mechanical load. Rupture can also be induced by processes such as cell death, and active cell membrane repair mechanisms are essential to preserve cell integrity. Pore-formation in cell membranes is also at the heart of many biomedical applications such as in drug, gene, and siRNA delivery. Membrane rupture dynamics has been studied in bilayer vesicles under tensile stress, which consistently produce circular pores. We observed very different rupture mechanics in bilayer membranes spreading on solid supports: in one instance fingering instabilities were seen resulting in floral-like pores; in another, the rupture proceeded in a series of rapid avalanches causing fractal membrane fragmentation. The intermittent character of rupture evolution and the broad distribution in avalanche sizes is consistent with crackling-noise dynamics. Such noisy dynamics appear in fracture of solid disordered materials, in dislocation avalanches in plastic deformations, domain wall magnetization avalanches. We also observed similar fractal rupture mechanics in spreading cell membranes.



#### 2740-Pos Board B726

##### Giant Unilamellar Vesicles with Internalized Poly-(n-Isopropylacrylamide)-Vinyl Ferrocene Copolymer (PNIPAAm-VFC), a New Membrane-Interactive Thermoresponsive Material

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It is very challenging to develop artificial systems mimicking components of the biological cell, but offers rewards with respect to a better understanding of cell

processes, function and complexity. Giant unilamellar vesicles are micro-sized biomimetic compartments. They possess a simple, very important structural feature of natural cells, the double layer membrane, but are otherwise limited in internal functionality. There are a few existing methods of introducing more complex internal structure into liposomes. Internalizing water soluble polymers like poly-N-isopropylacrylamide (PNIPAAm) or poly-ethylene glycol (PEG) is a suitable method to increase concentration, viscosity, and to achieve compartmentalization, thus approaching more complex artificial cell architectures [1-3]. This time we want to present a new type of thermoresponsive polymer, PNIPAAm with co-polymerized vinyl ferrocene (VFC)[4]. The increased hydrophobicity achieved by 3% (mass) ferrocene, promised better dynamic properties, reduced equilibrium compartment size and more homogenous hydrogels. During our investigation, an exceptionally strong interaction between PNIPAAm-VFC and the vesicle boundary was observed. Polymer chains are anchored in the bilayer membrane by means of the lipophilic metallocene groups, creating unexpectedly strong attachment points. After increasing the temperature above the lower critical solution temperature where gel formation sets in, numerous lipid nanotubes are pulled from the vesicle, connecting the vesicular membrane with the internal hydrogel compartment surface. This leads to spontaneous shape changes of the vesicle, associated with multiple protrusion formation, followed by rapid coarsening to a single liposome.

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#### 2741-Pos Board B727

##### Probing Membrane-Surface Interactions via Brownian Motion of Micro-Sized Beads

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Interactions between a free standing bilayer lipid membrane and various surfaces have been investigated by monitoring the Brownian motion of micron-sized silica beads on a GMO membrane. This membrane was suspended across a 200  $\mu\text{m}$  Teflon aperture in either water or buffer solution using the painting method. Silica beads with diameters ranging from 0.7  $\mu\text{m}$  - 5  $\mu\text{m}$  were spread on the membrane and their motions were recorded at a rate of 10 frames/sec. The beads were either left unfunctionalized after cleaning or further functionalized with various chemical groups, including amine, PEG, methyl, octadecyl, avidin as well as the membrane itself. Since the interface interactions between the membrane and the beads leads to increased friction, it would be detected if the bead slowed in comparison with free Brownian motion. Experiments showed that the membrane functions as a near-perfect surface, lacking non-specific interactions. In all cases, only the avidin-biotin and membrane-membrane interactions lead to retarded motion and only in a buffered solution. This study on the Brownian motion of micron-sized beads on a membrane provides a convenient novel probe to detect interface interactions. As the beads used in these experiments have similar sizes to most bacteria and cells, they can be treated as bacteria/cell analogues and used to simulate the adsorption of bacteria /cells on another membraned bioorganism.

#### 2742-Pos Board B728

##### Phospholipid Bilayers are Viscoelastic

Christopher W. Harland, Tristan T. Hormel, Miranda J. Bradley, Raghuveer Parthasarathy.

The two-dimensional fluidity of lipid bilayers is crucial to biological function, as it enables the mobility of membrane macromolecules. Though the existence of membrane fluidity is well established, its fundamental nature remains poorly characterized, and many models of membrane dynamics implicitly or explicitly assume that the lipid bilayer is a simple Newtonian liquid. Three-dimensional fluids as diverse as chocolates and cytoskeletal networks show a rich variety of Newtonian and non-Newtonian dynamics that have been illuminated by recently developed rheological techniques. Applying particle tracking micro-rheology to freestanding phospholipid bilayers, we find that the membranes are not simply viscous liquids but rather exhibit viscoelasticity, with an elastic modulus that dominates the response above a characteristic frequency that diverges at the fluid-gel (La-Lb) phase transition temperature. These findings fundamentally alter our picture of the nature of lipid bilayers and the mechanics of membrane environments.

